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Efficient allocation of online grocery orders

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Abstract: Despite some initial setbacks, the online grocery business is viable and growing. In this paper, we discuss the industry's value proposition, its business models, the various quality issues faced by an e-grocer and the trade-offs faced in the selection of a highly efficient fulfilment strategy. Brick and click grocers usually choose fulfilment from stores rather than distribution centres. However, store fulfilment is vulnerable to congestion and 'trolley rage' when pickers of online orders get in the way of traditional shoppers. We propose a management science model for efficient allocation of online grocery orders. The model shows the impact of delivery budget and overall utilisation on store congestion. Contrary to current practice, which typically allocates orders to the nearest store, our model shows the optimal solution. Practitioners can use the model to prevent customer dissatisfaction while researchers will find this study provides a basis for future model extensions and fine-tuning.

Keywords: delivery; distribution centre; efficiency; fulfilment; management science models; online groceries; order allocation; quality.

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1 Introduction

The grocery industry is extremely large with supermarket sales in the USA in 2004 of $457.4 billion (FMI, 2004). Unlike the UK, where the top three grocers control 59% of the market, the grocery industry in the USA is highly fragmented with the top 10 grocers controlling less than 50% of the market (Delaney-Klinger et al., 2003). In fact, despite recent mergers and acquisitions (Palmer et al., 2000), the USA has one of the least consolidated food retail industries in the western world (FMI, 2005). As a result, regional dominance is common, such as Albertsons and Safeway in the western states, Kroger in the Southeast, Midwest and neighbouring states (under different brands including King Soopers in Colorado), HEB in Texas, Wegmans in the Northeast and Ahold stores in the eastern states. On the other hand, in the UK, 96% of the population is close to a Tesco store and 72% of the population is close to a Sainsburys store (Boyer et al., 2005).

Razor thin margins in the industry, 0.88% in 2003–2004 (FMI, 2005), increase the pressure on food retailers to reduce costs, increase sales volume and operate efficiently. Traditional supermarkets face threats from discounters such as Wal-Mart, the top US food retailer in 2003, and CostCo, which was sixth in 2003 sales (FMI, 2005), and from specialist organic grocers such as Whole Foods, which has been growing much faster than the industry as a whole. Numerous other channels, such as convenience stores and drug stores, also compete for consumer food dollars. Moreover, the trend to eat out more frequently, particularly in fast-food outlets, has dampened supermarkets' profitability. Nearly half of the food dollars are spent on food away from home, compared with one quarter four decades ago (FMI, 2005).

The objective of this study is to present an example of how efficiency can be achieved in e-groceries through the use of management science models. We consider in detail the issue of order allocation to stores for a brick-and-clicks business. Order allocation is modelled as a convex programme where the objective is to minimise store congestion while meeting internet demand.

In the next section, we discusss online groceries, including quality issues, business models and fulfilment alternatives. We then explain how management science models can potentially solve many e-grocery logistic problems. Following is the order allocation model and its sensitivity analysis. Finally, we provide managerial insights and implications and suggestions for future research.

2 Online groceries

In this highly competitive and threatened environment, most traditional supermarkets have been risk averse and reluctant to venture into online business. The pioneers in online

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groceries were pure play firms, such as Peapod, Streamline, Shoplink, WebVan, HomeGrocer, and GroceryWorks. Plentiful venture capital during the dotcom boom provided resources for experimentation with innovative ideas. However, many failures resulted from unconstrained spending by the pure plays and slower than expected consumer adoption of buying groceries over the internet. Most of the pure play pioneers were acquired or closed down during the dotcom bust. For example, Safeway acquired GroceryWorks, Ahold USA acquired Peapod and Streamline, and Shoplink and Webvan closed down (Entrikin, 2002, Hays et al., 2004).

Online grocery revenue is currently less than 1% of total supermarket sales, and only about 25% of the optimistic forecasts issued before the demise of Webvan and the dotcom bust. Nevertheless, the internet niche is growing faster than the grocery business as a whole, according to Jupiter Research (Fishman, 2005). Online revenue has grown from $235 million in 1998 to about $2.4 billion in 2002 and is projected to reach $4.9 billion by 2006 (Hays et al., 2004; Lee, 2003). Sales at several e-grocers have increased more than 50% per year over the last two years (Boyer et al., 2004). FreshDirect, for example, in 2004 had a monthly sales increase of 25% and an increase in active customers of fourfold from a year earlier (Harsany, 2004). FreshDirect has at times not been able to keep up with the demand, and once had to refuse about 1000 orders because it was overwhelmed (Straziuso, 2004).

In Europe, 10% of total grocery revenue is expected to be online by 2010. In the UK, the online market was $1 billion in 2000 and is thriving more than in the USA, partly explained by the smaller degree of fragmentation of UK grocers; the denser population, which facilitates efficient deliveries; and the greater inconvenience for consumers having to travel to stores (Delaney-Klinger et al., 2003). Online sales at Tesco UK, the world's largest online grocer, increased 29% in 2004 to 577 million pounds, which was more than ten times the volume in 2000 (Tesco, 2004).

The advantage of online grocery shopping for consumers includes convenience and higher quality, fresher food (Boyer et al., 2004; Fishman, 2005; Laseter et al., 2003; Tanskanen et al., 2002). Although the first time online order takes about an hour, consumers save time by reusing their shopping lists, resulting in subsequent orders averaging only 20 min (Boyer et al., 2004; Ellis, 2003; Fishman, 2005). Other online conveniences offer the ability to: add to the saved shopping list over several days, e-mail lists to other family members, comment on items, receive personalised coupons, sort items by calorie count or nutritional information such as sodium content, order the ingredients for 'one click meals' automatically from online recipes (Entrikin, 2002, Fishman, 2005, Internet Retailer, 2004). Furthermore, food is fresher and of higher quality when processed under strict temperature control and shorter supply chain in online grocers' distribution centres.

However, consumers' ingrained shopping habits are difficult to change (Hays et al., 2004; Kallio et al., 2000; Palmer et al., 2000; Tanskanen et al., 2002) and customers may be reluctant to pay the delivery charge (Entrikin, 2002; Fishman, 2005). Although the demand is increasing, customer acquisition costs range from $200 to $700 so it is critical for e-grocers to provide high quality products and service to gain loyalty and retain customers who often ventured online hesitantly (Ellis, 2003; Hays et al., 2004; Tanskanen et al., 2002). If consumers are disappointed in their online experience they may stay away indefinitely and also discourage others from trying online grocery shopping. The quality issues that need to be addressed by online grocers are discussed next.

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3 Quality issues

There are many challenges for e-grocers to overcome. Product quality is difficult to evaluate online, especially for non-packaged items such as produce (Boyer et al., 2004). Other than packaged goods, many of the products sold are non-standard items, which are more difficult to describe and represent online than standard items. Again, fruit is an example that varies from item to item, unlike branded packaged goods.

Many grocery products are 'touch and feel' items that customers prefer to inspect before purchase (Boyer et al., 2004). Fewer sensory cues are available online than in the physical stores where people often smell and touch fruit to assess whether it is fresh and ripe. The degree of ripeness desired is highly personal. For example, some people like to buy bananas that are green while others prefer their bananas yellow. Online grocers need to provide a way of communicating the ripeness available and the ripeness desired. Some sites, such as Peapod, do this by providing a comment box for consumers to specify what ripeness they want (Entrikin, 2002).

Substitution for items out of stock is a problem online since the picker does not know what would satisfy the customer. For example, non-delivery of an item needed in a recipe will annoy customers, but substituting a different brand may also result in dissatisfaction. A consumer study of 40 online orders found none of the shoppers received their full order, and around a fifth of the substitute items were unacceptable (Hoyt, 2001). Consumers' logic for substitution is intuitive and highly personal. To compensate for this problem, Peapod shows consumers online what will be substituted if their first choice is not available (Fishman, 2005).

Another quality challenge for e-grocers is handling soft fruit and other fragile items, which can easily be squashed or damaged (Boyer et al., 2004). Training employees in the importance of picking and packing carefully is critical (Fishman, 2005) since online grocers need to build trust and avoid consumer dissatisfaction. Online grocers typically pack items in sturdy boxes or crates for delivery rather than bags to prevent damage to fragile items.

Many grocery products are temperature sensitive. Refrigerated and frozen items can spoil easily unless the temperature is controlled. Most, if not all, online grocers are very careful with temperature control and use refrigerated trucks and vans. For example, FreshDirect keeps food at 36°F or below all the way through production and packing at its processing centre, and in its trucks during shipping (Kirkpatrick, 2002). Food is only exposed to warmer air when the delivery person removes an order from the truck. In contrast, during the traditional value chain groceries typically go through temperature fluctuations as they pass from wholesaler to truck to grocer to customer cart and home. Supermarkets choose temperatures for shoppers' comfort, while distribution centres choose ideal temperatures for the food. FreshDirect, which has 12 different temperature zones in its processing centre, professes that it sells a better quality product, since it gets groceries to the consumer faster with better temperature control (Hays et al., 2004; Kirkpatrick, 2002).

Delivery is also challenging and expensive because of the varied temperature control needed in the trucks or vans (Kallio et al., 2000). For example, SimonDelivers uses boxes that can keep ice cream frozen for 8 h in 80°F weather and picks up the boxes on the next delivery (Fishman, 2005). Also the items are often bulky and heavy even though their relative value is often very little (Boyer et al., 2004; Kallio et al., 2000). The high volume to value ratio increases the relative cost of delivery since more trucks and drivers are needed than otherwise.

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4 Online grocery business models

Current and defunct online grocers have used various business models (Palmer et al., 2000). Tesco, the largest home delivery grocer in the world, has store proximity to 96% of UK's population (Boyer et al., 2004). Its business model, focusing on incremental improvement to lower risk, is based on fulfilment from stores. Employees use special carts called 'picking trolleys' mounted with screen guides and 'shelf identifier' software instructing them where to pick the items in the list (Hays et al., 2004; Hoyt, 2001). However, this procedure is labour intensive so Tesco has not ruled out centralised distribution centres in the future when justified by the volume of orders.

FreshDirect in New York is a successful online grocer with an interesting and unique business model based on make-to-order, a similar concept to that used successfully by Dell Computer (Laseter et al., 2003). FreshDirect has 8% margins, much higher than margins for groceries in general, and achieves this by specialising in providing high quality fresh food. More details on FreshDirect's strategy are discussed in the following section.

The e-grocer failures often used business models that had not been validated. Most pure play start-ups overestimated the demand for buying groceries online and underestimated the logistic problems. For example, Webvan aspiring to leverage the 'last mile', spent over $1.2 billion on huge highly automated warehouses, which despite many innovations, were much too costly and had far too much capacity for the demand at that time (Boyer et al., 2004).

Similarly, Streamline was a victim of the dotcom bust, although its business model had many innovative features. Shoplink had a similar business model, but also did not survive. Streamline targeted two income families with children, provided a 'don't run out' service which automatically replenished the consumer's inventory of continuously-needed items and scheduled delivery every week (Hays et al., 2004; Kallio et al., 2000; Kämäräinen et al., 2001; Tanskanen et al., 2003). SimonDelivers now uses a similar 'newspaper route delivery' model to help control costs (Internet Retailer, 2004). Streamline offered goods and services beyond groceries, such as videos and dry cleaning (Hays et al., 2004). Surprisingly, although using the 'last mile' to provide products and services beyond groceries increases margins, with the exception of Tesco and Schwans, currently most online grocers ignore this opportunity (Hays et al., 2004; Internet Retailer, 2004). Streamline also offered unattended delivery to a refrigerator in the customer's garage using a lockbox for entry (Entrikin, 2002; Kallio et al., 2000; Kämäräinen et al., 2001). Unattended delivery is no longer common, although Peapod and SimonDelivers leave insulated coolers packed with dry ice; and Netgrocer uses Fedex to deliver non-perishables (Boyer et al., 2005; Entrikin, 2002; Hays et al., 2004; Palmer et al., 2000). Research has suggested other forms of unattended delivery, such as secured delivery boxes and shared reception boxes, to capture cost savings from avoiding tight delivery windows (Punakivi et al., 2001; Punakivi and Tanskanen, 2002).

Brick-and-click grocers usually pick and deliver from their stores. Albertsons, Safeway and King Soopers are only online in limited cities. Albertsons offer delivery in Seattle, Portland, San Francisco, Los Angeles/San Diego, Las Vegas, and Boise (Boyer et al., 2005). Safeway, based on a partnership with GroceryWorks and Tesco, offers online delivery services in Seattle, Portland, San Francisco, Los Angeles and San Diego (Hays et al., 2004). GroceryWorks' business model started with one large warehouse, changed to multiple, smaller warehouses, and currently relies on in store picking. King Soopers, a

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Kroger brand, is currently only online in Colorado. Kroger.com has an 'Order Online, Send Anywhere' option for gift cards, flowers, premium meats and premium fruits. Ahold USA, which acquired Peapod (Entrikin, 2002) and Streamline, is online at the peapod.com site and delivers to 15 markets around the Midwest and East Coast, such as Westchester (Fishman, 2005). It has a hybrid business model using distribution centres and stores (Entrikin, 2002; Fishman, 2005).

Another business model that several brick-and-click grocers offer is pick-up from the stores and other locations (Boyer et al., 2004; Entrikin, 2002; Hays et al., 2004; Kallio et al., 2000). HEB attempted and abandoned online shopping offerings, but did offer pick-up for some time. Albertsons and Lowe's Foods To Go in North Carolina offer customer drive-thru pick-up at several stores. FreshDirect currently offers pickup at its processing center, arranges pickup at sports events and at corporations with more than 1000 employees (freshdirect.com, 2005), and also previously offered pickup at train stations (Hays et al., 2004).

Niche business models include organic food and ethnic food (Hays et al., 2004; Palmer et al., 2000). Some examples of organic grocers include: DoortoDoorOrganics, OrganicBox, OrganicExpress, Organics to You, Planet Organics, Pioneer Organics, Suburban Organics, Urban Organics, and Westside Organics (Boyer et al., 2005). Whole Foods abandoned their online store and now has a partnership with Gaiam, which offers only a very limited selection. Some examples of ethnic grocers include: Asian and Mexican, Cajun-shop, ImportFood.com, MahaBazaar and TempleofThai (Boyer et al., 2005). Most ethnic online grocers deliver widely to all states regardless of their actual location. Start-ups can outsource the website and backend systems by leveraging services provided by MyWebGrocer, an IT and software provider for approximately 30 grocers.

In the UK, apart from Tesco, Asda (purchased by Wal-Mart Stores in 1999) added a web-based order system, ASDA@home, in mid-2001, but it only delivers in selected areas from dedicated warehouses (Hoyt, 2001); Ocado, a start-up grocer that partnered with Waitrose stores, delivers to London from a distribution centre (Boyer et al., 2002), and Sainsburys can deliver to 72% of the U.K. (Boyer et al., 2005). Currently, Sainbury's employs a hybrid picking model based on two dedicated picking centers and in store picking in 33 stores (Hays et al., 2004; Hoyt, 2001).

The three most dominant surviving business models are:

- fulfilment from stores by 'brick-and-click' supermarkets, such as Tesco and Safeway
- fulfilment from distribution centres, such as FreshDirect in New York and Ocado in London (Boyer et al., 2004)
- hybrid strategies, such as used by Peapod and Sainbury's (Hays et al., 2004).

5 Tradeoff between fulfilment from distribution centers and stores

Distribution centres aggregate supply and demand, providing the potential for higher productivity than fulfilment from stores (De Koster, 2002; Kämäräinen et al., 2001). On the other hand, fulfilment from stores involves lower risk since the required investment is much less. The high cost of building a distribution centre may not be justified by the return on investment (Boyer et al., 2004; Hays et al., 2004). Insufficient demand will result in overcapacity in the distribution centre, which led to the downfall of Webvan. Efficiency

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gains from automation depend on utilisation of capacity. Many stores have slack times when employees are available to pick items for online orders. Also stores, being more dispersed than distribution centres, are closer to the customers so delivery vans have less distance to travel and are not as likely to be delayed by traffic which might prevent them from delivering in the promised time window. This is important because one late delivery could discourage a customer from shopping online (Fishman, 2005). Despite the advantages of store-based picking models, e-grocers using the distribution centre business model, such as Ocado, believe that they can deliver groceries to customers' homes more effectively (Boyer et al., 2002). Following are potential productivity improvements from distribution centre fulfilment.

Since the distribution centre does not need to be in a prime residential location close to customers, the distribution centre has lower real estate costs than stores. For example, FreshDirect's distribution centre in Long Island City is across the river from Manhattan in New York. Although real estate is less expensive than Manhattan, FreshDirect's delivery vans travel less than a quarter of a mile to the Midtown tunnel and have quick access to the highest population density in the USA (Laseter et al., 2003).

Distribution centres lower inventory costs from centralisation and aggregation of goods (Boyer et al., 2004). This is especially beneficial for perishable items. In contrast, traditional decentralisation results in stock-outs at some stores and excess inventory at other stores. Stock-outs result in customer dissatisfaction while excess inventory increases costs. Neither of these alternatives is desirable and the short shelf-life of perishables precludes transferring the inventory among stores.

The supply chain is more efficient with disintermediation of the stores (Boyer et al., 2004). Disintermediation saves time and money and requires fewer employees. Also disintermediation reduces the inventory throughout the supply chain. FreshDirect usually has about one day of seafood inventory versus seven–nine days inventory in a typical store (Laseter et al., 2003).

Food is higher quality and fresher direct from a distribution centre because there is less handling during distribution and a shorter supply chain (Fishman, 2005; Laseter et al., 2003). In the stores, handling is needed to unpack boxes and put items on the shelf, and further handling occurs when potential customers touch items yet do not purchase them. For example, people often want to squeeze tomatoes before buying them. According to a study, each tomato is touched on average 11 times before it ends up in the home of the final customer in a supermarket supply chain, versus touched only three times when stores are disintermediated (Tanskanen et al., 2002). The shorter supply chain results in the consumer receiving the food more quickly after the fruit is picked or the fish is caught (Boyer et al., 2004; Hays et al., 2004). For example, the 'dock to door' time for seafood is often less than 24 h at FreshDirect (Laseter et al., 2003).

Products from a distribution centre are higher quality because of more efficient temperature control and more specialised employees, who are better trained in handling goods (Delaney-Klinger et al., 2003; Fishman, 2005; Laseter et al., 2003).

Distribution centres provide better selection for customers because of centralisation and scale (Hays et al., 2004). Items are less likely to be out of stock and therefore there is less need for substitution (Boyer et al., 2004). As discussed earlier, although e-grocers such as Peapod show consumers online what will be substituted if their first choice is not available (Fishman, 2005), substitution risks customer dissatisfaction, is inefficient for pickers, and is potentially problematic in online shopping since it is impractical for the consumer to specify substitutes for every item ordered.

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There is more efficient picking and packing at the distribution centre because of automation, such as conveyer belts and lights to indicate what is needed (Hays et al., 2004). Errors are more likely to occur at stores since employees have fewer tools to assist them, more distractions exist, and there is less of an assembly line environment. Store layouts are designed for display rather than for picking efficiency (Kämäräinen et al., 2001). Picking rates in distribution centres have been estimated at 300–450 items per hour, or three–four times the store-picking rate and up to 20 times the consumer-picking rate (Delaney-Klinger et al., 2003; Kämäräinen et al., 2001).

Distribution centres are not subject to 'trolley rage' which occurs from stress in crowded supermarkets, where regular shoppers get annoyed when employees picking online orders cause congestion (Boyer et al., 2002; Brown et al., 2003; Delaney-Klinger et al., 2003). It is especially an issue in the UK where grocers sell three times ($1500 Sales/Sq Ft.) as much in the same amount of space as US grocers ($500 Sales/Sq Ft.).

Distribution centres have more efficient delivery because their scale makes it easier to plan and use the capacity of the delivery van or truck efficiently, especially in densely populated cities such as New York and London (Boyer et al., 2002). FreshDirect averages nine–ten deliveries per hour, which is three times more than what Webvan struggled to achieve (Laseter et al., 2003). Its cost efficient delivery strategy implements constraints (Boyer et al., 2004) such as restricting delivery times to concentrate demand, using a crew of two instead of one and targeting a high-density population (Laseter et al., 2003).

In summary, distribution centres enable more efficient inventory control, picking, packing and delivery than store fulfilment. Consumers receive higher quality, fresher food and fewer substitutions and stock-outs than they would from store fulfilment. On the other hand, distribution centres require a higher fixed investment cost, and a longer lead-time to set up. Currently, only highly populated cities, like New York and London, have proven to have enough concentrated demand to justify large distribution centres. Hybrid business models attempt to capture the advantages of both stores and distribution centres. The trade-offs among the alternatives can be modelled using management science.

6 Management science models for e-groceries

For a self-sustaining e-grocery operation it is imperative that emphasis be placed on high levels of efficiency in both delivery and quality of customer service. Management science provides a rich set of models that are potentially of value in efficiently running an e-grocery business. Below we give several examples where management science models may be used. We restrict our discussion to facility location (Drezner and Hamacher, 2004; Owen and Daskin, 1998), order allocation (Scott and So, 1994), and order fulfilment (Ghiani et.al., 2003; Ball et. al., 1995).

Early e-grocery vendors built huge automated warehouses to service a wide geographic area. The sizing of such a warehouse and its location can be modelled as a mathematical programme where one trades-off warehouse related costs (fixed plus operating) against delivery costs. Another mode of operation tested by e-grocery vendors has been to position delivery vehicles at strategic locations, such as shopping malls or train stations, where customers can collect a previously placed internet order.

Published literature exists on location regarding both manufacturing and service facilities, which could relate to the e-grocery business. Once an order is placed on an

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internet site, it needs to be fulfilled. However, if the vendor is using a brick-and-click site, it must first be allocated to a particular store for assembly and ultimate delivery. If adequate capacity exists in a bricks-and-mortar network of existing stores, it may be a simple matter of allocating the order to the nearest store. Yet as more orders are allocated to a particular store, it may get congested and delay ultimate delivery. Further as congestion increases, the store becomes subject to 'trolley rage' as alluded to earlier. In this case, another store may be optimal for the purpose of assembly and delivery of the order. This is the order allocation problem and will be the subject of the model described in the next section.

Once an order has been allocated and assembled at a store, detailed scheduling is needed. This includes assigning an order to a particular truck, routing that truck and possibly delivering the order within a promised time window. Many operations research models have been developed to answer these questions.

Although it would be advantageous to answer all the above questions simultaneously, we envisage they would be addressed in a hierarchical manner. This is a common approach in the design and operation of distributed service networks for example (Ahituv and Berman, 1988). We now turn to a detailed model for order allocation.

7 An order allocation model

Suppose a region has N stores which meet the immediate needs of walk-in customers as well as internet orders. Also assume that in the region under consideration, customers may be grouped into M distinct geographic groups. For example, a group could represent all customers on a street block. It is desired to find that allocation of customer orders to stores that minimises delivery cost within a specified average service time.

We introduce the following notation.

Index set: stores i = 1, . . . ,N; customers j = 1, . . . ,M.

μ_i = capacity of store i

λ_{0i} = walk-in demand at store i

d_j = Internet demand by customer j

c_{ij} = cost to deliver service to customer j from store i

C = budget allocated to meet internet demand

δ_{ij} = internet demand from customer j allocated to store i

λ_i = internet demand allocated to store i.

In order to simplify analysis, we represent each store as an M/M/1 queuing system with arrival rate $\lambda_i + \lambda_{0i}$ and service rate μ_i, where μ_i is the capacity of the store. (More general models could be added here but this will suffice for our purposes.) The objective of the model is to allocate internet demand so that the wait time in each store is approximately the same where we use wait time as a surrogate measure of store congestion.

For a store i following an M/M/1 queuing system, the wait time is given by

$$1/(\mu_i - (\lambda_i + \lambda_{0i}))$$

which is convex in λ_i. Hence we may pose the following convex optimisation problem.

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Minimise

$$\underset{i=1,\ldots,N}{\text{Maximum}} \quad 1/(\mu_i - (\lambda_i + \lambda_{0i})) \tag{1}$$

subject to

$$\sum_{i}^{N} \delta_{ij} = d_j, j = 1, \ldots, M \tag{2}$$

$$\sum_{j}^{M} \delta_{ij} = \lambda_i, i = 1, \ldots, N \tag{3}$$

$$\lambda_i + \lambda_{0i} \leq \mu_i, i = 1, \ldots, N \tag{4}$$

$$\sum_{i}^{N} \sum_{j}^{M} c_{ij} \delta_{ij} \leq C \tag{5}$$

$$\delta_{ij} \geq 0, i = 1, \ldots, N; j = 1, \ldots, M. \tag{6}$$

Here the objective given by Equation (1) represents the maximum wait time (congestion) at each store, which is to be minimised. Constraints (2) and (3) represent the internet demand at each customer and serviced by each store respectively. Constraint (4) guarantees that the capacity of each store to service internet demand is not exceeded and constraint (5) ensures that the maximal budget in servicing internet demand is not exceeded. Note that the above model could include a distribution centre, which would be the same as a store with no walk in demand.

It is readily seen that the above programme is convex and a global solution will result upon application of a non-linear optimiser. Since the objective is non-differentiable, it would generally be solved by converting to the equivalent form.

Minimise

$$W \tag{7}$$

subject to

$$1/(\mu_i - (\lambda_i + \lambda_{0i})) \leq W \quad i = 1, \ldots, N. \tag{8}$$

and constraints (2)–(6).

8 Solution and sensitivity analysis

8.1 Base case

Set the number of stores N = 3 with equal capacities of 200 and walk-in average demand of 140, 160, and 120 respectively. Set the number of customers M = 9 with demands 30,

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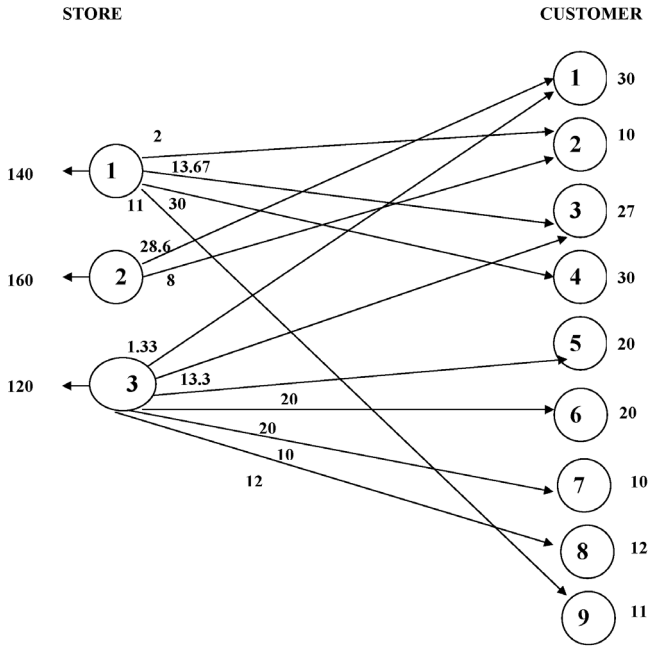
10, 27, 30, 20, 20, 10, 12, and 11, respectively. Let the budget be limited to C = 500 units. Unit costs are given in Table 1.

Table 1 Delivery cost/order

	Store/customer								
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1	6	7	3	2	9	5	4	4	3
2	4	5	8	8	7	7	2	1	4
3	6	8	4	4	2	1	1	1	7

An optimal solution for the base case is given in the network Figure 1.

Figure 1 Optimal solution: base case



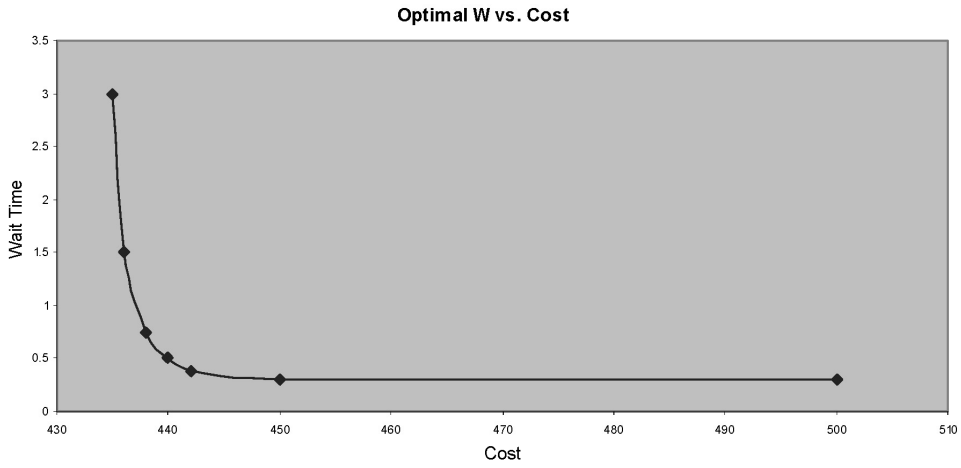
For example, store 1 which has 140 units of walk-in demand sends 2, 13.67, 30, and 11 units to customers 2, 3, 4, and 9 respectively. Customer 4, which demands 30 units, receives all its delivery from store 1. The minimal wait time is W = 0.3 units which is achieved at all stores. Hence, in the optimal solution, the model attempts to achieve equity of workload among all stores thus minimising the chances of congestion at any one while staying within the delivery budget. In some cases, all orders to a customer region will be serviced from the one store; in others the budget and congestion considerations will preclude this.

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We next look at the impact of the budget C on the wait time by decreasing the budget from its initial value at 500 units. Results are portrayed in Figure 2 below.

Figure 2 Optimal wait time vs cost



We see that the optimal wait time remains at 0.3 units as C is reduced to 450 units and then increases sharply as C is further reduced. Consequently as the budget C is reduced below 450, the base case optimal allocation of orders that equalises work levels at all stores breaks down and the maximal wait time (congestion) increases rapidly and negatively impacts the performance of the system.

It is convenient to define a total utilisation factor as

$$U = \frac{\sum_{j=1}^{M} d_j + \sum_{i=1}^{N} \lambda_{0i}}{\sum_{i=1}^{N} \mu_i}$$

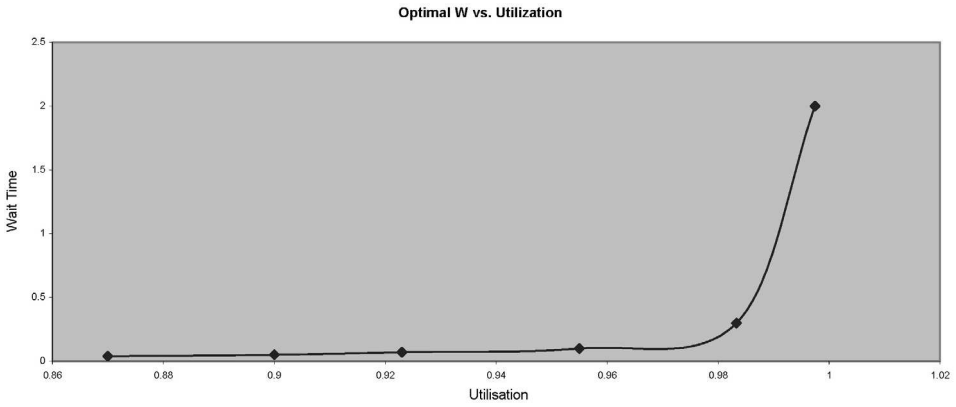
which is the ratio of the total demand (internet plus walk-in) and the total store capacity. It is essentially the fraction of utilised capacity. We require this to lie between 0 and 1 with lower values indicating ample capacity to flexibly meet demand. As either internet or walk-in demand increases, this will increase causing congestion to increase in stores. In Figure 3, we show how the wait time varies with changes in utilisation.

In the base case, utilisation is 0.94 and as this is increased either by additional walk-in traffic or internet demand, the wait time increases significantly. Conversely as utilisation drops off below 0.94, the wait time decreases significantly indicating that management needs to carefully monitor utilisation in order to efficiently serve customers. Recall that at times, Fresh Direct has had to turn away customers, as utilisation became too high.

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Figure 3 Optimal wait time vs utilisation



The model has several important implications for managerial decision making. It allows management to effectively budget for servicing internet demand in such a way that minimally impacts the every day operations of a store. If demand is expected to increase over time either from additional walk-in or online customers, the model enables management to proactively plan for additional capacity at a store or to adjust by diverting demand to a dedicated distribution centre. Given a forecast of future demand, it highlights when a dedicated distribution centre will be needed thus allowing management to plan proactively.

9 Conclusions

The e-grocery business is growing. To date, the successful business models have been the brick-and-click stores and a few niche companies delivering in densely populated regions. As customer perceptions change and as customers become more aware of the convenience and high quality of e-grocery delivery, the industry is likely to thrive. In this paper, we have discussed various business models, their strengths and shortcomings. We have posited that efficiency and quality are key drivers. Efficiency can be achieved by a judicious use of management science models and various avenues for application have been suggested. Furthermore, we develop in detail one model for order allocation where we draw conclusions about the effect of delivery budget and resource utilisation on overall efficiency. The model illustrates that management must pay careful attention to both the delivery budget and overall utilisation or significant congestion and non-equitable workloads will result. As explained earlier, congestion may decrease picking efficiency and the quality of shopping for traditional consumers. Since online grocers need to avoid customer dissatisfaction arising from congestion, the typical practice of allocating orders from the nearest store is not always optimal. Our model can assist practitioners and provides a basis for future research on allocation of online grocery orders. The model given implicitly assumes that demand is available to be allocated by a particular time, say 6am. An extension of the model could look at the real-time allocation of orders in the sense that orders received at any time could be allocated and a delivery window promised. The model also assumes that the allocation process is independent of the routing and scheduling of deliveries. Future research could look at simultaneous allocation, routing and scheduling decisions.

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References

Ahituv, N. and Berman, O. (1988) *Operations Management of Distributed Service Networks*, New York: Plenum.

Ball, M.O., Magnanti, T.L., Monma, C.L. and Nemhauser, G. (Eds) (1995) 'Network routing', in *Handbooks in Operations Research and Management Science*, Vol. 9, Amsterdam: North Holland.

Boyer, K., Frohlich, M. and Hult, T. (2004) *Extending the Supply Chain: How Cutting-Edge Companies Bridge the Critical Last Mile into Customers' Homes*, Amacom.

Boyer, K., Hult, T. and Frohlich, M. (2002) 'Ocado: an alternative way to bridge the last mile in grocery home delivery', Case No. 602–057–1, European Case Clearing House, Wharley End.

Boyer, K., Hult, T. and Frohlich, M. (2005) 'List of home delivered grocers and food providers', http://nebula.bus.msu.edu/grocerysurvey/LastMileWeb/list_of_grocers.html

Brown, M., Pope, N. and Voges, K. (2003) 'Buying or browsing?: An exploration of shopping orientations and online purchase intention', *European Journal of Marketing*, Vol. 37, Nos. 11–12, pp.1666–1684.

De Koster, R.M.B. (2002) 'Distribution structures for food home shopping', *International Journal of Physical Distribution and Logistics Management,* Vol. 32, No. 5, pp.362–380.

Delaney-Klinger, K., Boyer, K. and Frohlich, M. (2003), 'The return of online grocery shopping: a comparative analysis of Webvan and Tesco's operational methods', *The TQM Magazine*, Vol. 15, No. 3, pp.187–196.

Drezner, Z. and Hamacher, H.W. (2004) *Facility Location*, 2nd edition, Springer.

Ellis, C. (2003) 'Lessons from online groceries', *Sloan Management Review*, Vol. 44, No. 2, p.8.

Entrikin, R. (2002) 'The online grocery industry', working paper George Mason University. available at: http://www.cba.ufl.edu/crer/Publications/THE%20ONLINE%20GROCERY%20INDUSTRY.doc

Fishman, T.C. (2005) 'Click here for tomatoes', *Money Magazine,* April, pp.143–146.

FMI Food Marketing Institute (2004) 'Facts and figures, supermarket facts industry overview 2004' available at: http://www.fmi.org/facts_figs/superfact.htm, accessed May 11, 2005.

FMI Food Marketing Institute (2005) 'Competition and profit', available at: http://www.fmi.org/facts_figs/CompetitionandProfit.pdf, accessed May 11, 2005.

freshdirect.com (2005) 'Delivery and pickup info', available at: http://www.freshdirect.com/help/delivery_info_depot.jsp

Ghiani, G., Guerriero, F., Laporte, G. and Musmanno, R. (2003) 'Real-time routing', *European Journal of Operations Research*, Vol. 151, pp.1–11.

Harsany, J. (2004) Web Grocer Hits Refresh, PC Magazine, May18, available at http://www.pcmag.com/print_article2/0,2533,a = 125495,00.asp

Hays, T., Keskinocak, P. and Malcome de Lopez, V. (2004) 'Strategies and challenges of internet grocery retailing logistics', in E. Akcali, J. Geunes, P.M. Pardalos, H.E. Romeijn, and Z.J. Shen (Eds) *Applications of Supply Chain Management and E-Commerce Research in Industry*, Boston: Kluwer Academic Publishers, Chap. 8, pp.217–252.

Hoyt, D. (2001) 'Tesco delivers', Case Number EC 32, Graduate School of Business, Stanford University, September 2001.

Internet Retailer (2004) 'Food and drug: finding the right mix of product, service and fulfillment', available at: http://www.internetretailer.com/article.asp?id = 13491

Kallio, J., Saarinen, T., Tinnilä, M. and Tuunainen, V.K. (2000) 'Business model for electronic commerce: analysis of grocery retailing industry', in R.H. Hansen, M. Bichler, and H. Mahrer, (Eds) *Proceedings of the 8th European Conference on Information Systems, ECIS 2000 A Cyberspace Odyssey,* Vienna University of Economics and Business Administration, Vol. 2, pp.1037–1044.

Patent Owner, Consumeron, LLC - Ex. 2010, p. 14

6252 ijpqm 07.scott.qxp 29/11/2005 21:03 Page 102

Kämäräinen, V., Småros, J., Holmström, J. and Jaakola, T. (2001) 'Cost-effectiveness in the e-grocery business', *International Journal of Retail and Distribution Management,* Vol. 29, No. 1, pp.41–48.

Kirkpatrick, D. (2002) 'The Online Grocer Version 2.0: Forget Webvan, say the founders of FreshDirect. Their business is about food – and that's why they're sure it's going to succeed', *Fortune*, Nov 25, v146, i11, pp.217–221.

Laseter, T., Berg, B. and Turner, M. (2003) 'What FreshDirect learned from Dell', *Strategy & Business*, Spring, pp.1–6.

Lee, L. (2003) 'Online grocers: finally delivering the lettuce', April 28, *Business Week*, available at: http://www.businessweek.com/magazine/content/03_17/b3830074.htm

Owen, S.H. and Daskin, M.S. (1998) 'Strategic location models', *European Journal of Operations Research*, Vol. 111, pp.423–447.

Palmer, J. et al. (2000) 'Online grocery shopping around the world: examples of key business models', *Communications of AIS*, Vol. 4, Article 3, pp.1–44.

Punakivi, M. and Tanskanen, K. (2002) 'Increasing the cost-efficiency of e-fulfilment using shared reception boxes', *International Journal of Retail and Distribution Management*, Vol. 30, No. 10, pp.498–507.

Punakivi, M., Yrjölä, H. and Holmström, J. (2001) 'Solving the last mile issue: reception box or delivery box?', *International Journal of Physical Distribution and Logistics Management*, Vol. 31, No. 6, pp.427–439.

Scott, C.H. and So, K.C. (1994) 'Optimal allocation of work orders in a multi-echelon factory network', *Journal of the Chinese Institute of Industrial Engineers*, Vol. 11, pp.105–110.

Straziuso, J. (2004) 'Internet grocers stage quiet comeback', *InformationWeek*, May 17, 2004, available at: http://www.informationweek.com/story/showArticle.jhtml?articleID = 20301267

Tanskanen, K., Yrjölä, H. and Holmström, J. (2002) 'The way to profitable internet grocery retailing – 6 lessons learned', *International Journal of Retail & Distribution Management,* Vol. 30, No. 4, pp.169–178.

Tesco (2004) Tesco PLC Annual Review and Summary Financial Statement 2004, available at:http://www.tescocorporate.com/images/Review_04_0.pdf, accessed October 1, 2005.

Patent Owner, Consumeron, LLC - Ex. 2010, p. 15